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(54) PRIME MOVER SYSTEM

(71) We, WALLACE LOUIS MINTO, of 540 North Spoonbill Drive, Sarasota, Florida, United States of America, and LEONARD JAMES KELLER, of 8401 Shepard Street, Sarasota, Florida, United States of America, both citizens of the United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to prime mover systems.

In U.S.A. Patent No. 3,479,817 and in British Patent Specification No. 1,251,484 there are described external combustion engine systems employing as a drive medium in a closed sealed circuit, fluorocarbon compounds having low latent heats of vapourisation and desirable boiling points. While the systems described in the aforesaid British and U.S.A. patents are in many respects superior to the conventional prime mover systems employing steam as the drive medium, the use therein of conventional vapour engines, as typified by the turbine and reciprocating engine is accompanied by numerous drawbacks and disadvantages. These drawbacks and disadvantages are consequent to the operating and flow characteristics of the conventional engines particularly when employed with the fluorocarbon drive medium, whose properties in many critical areas are radically different from that of steam. In addition to the usual drawbacks of the reciprocating engine, including high inertial losses, poor torque speed characteristics, high friction and high maintenance requirements, the high losses and inefficiencies attendent to the operation of that engine due to the numerous changes in the direction of flow of the drive medium through the engine are aggravated by the use of a fluorocarbon drive medium because of its relatively high specific weight. The turbine, on the other hand, is a low-torque engine which in many applications requires the use of expensive energy-consuming speed reducing transmissions, is inefficient at low speeds, requires relatively high inlet-exhaust pressure difference, and has a relatively high size to torque ratio. Thus the use of reciprocating engines or turbines with fluorocarbon drive medium leaves something to be desired.

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The object of the present invention is to provide a prime mover system which has a high efficiency, ruggedness, simplicity, excellent torque and speed characteristics, low maintenance requirements, and great reliability, adaptability and versatility.

According to the present invention there is provided a prime mover system comprising a closed sealed circuit containing a drive medium having a latent heat of vapourisation of less than 100 gram calories per gram and a boiling point less than 95°C. at atmospheric pressure, said closed sealed circuit comprising:

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a vapour engine including at least two male and female members defining oppositely pitched helical screws intermeshing along a longitudinally extending area of engagement and extending from a leading input end to a trailing outlet end, a casing housing the screws and having faces in substantially fluid tight engagement with the peripheries of the screws and an inlet communicating with the leading section of the female screw and an outlet port communicating with the trailing end of the female screw, the female screw having chamber defining grooves and the male screw having helical lobes engaging the chambers along the intermeshing area, the screws rotating in predetermined opposite directions under the influence of a pressurised fluid introduced through the input port;

means including an input and an output for heating and vapourising the drive medium;

means including a condenser having an input and output for cooling and liquifying the drive medium;

means for injecting liquid drive medium from the cooling and liquifying means into the heating and vapouring means input;
means connecting the output of the heating and vapourising means to the input of the engine; and
means connecting the output of the engine to the input of the cooling and liquifying means.

An output drive shaft is connected to one or both screws and projects by way of suitable seals or glands through the casing. It should be noted that more than two intermeshing rotor screws may be employed, for example two female rotors engaging a common male rotor. Examples of mechanisms which may be employed and modified for the present purposes are described, in among others. U.S. Patent Nos. 1,696,802, 2,578,196 and 3,016,842.

The drive medium should be a fluorocarbon compound, preferably having at least two carbon atoms and three fluorine atoms per molecule, and in addition may contain hydrogen, oxygen, silicon and chlorine atoms in any desired combination to obtain the optimum thermodynamic properties desired. Mixtures and azeotropes of two or more of the above compounds may be employed as the drive medium and there may be added a suitable compatible high boiling point lubricant which is liquid at normal operating pressures and temperatures, preferably a fluorosilicone lubricant. The above fluorocarbon compounds are characterised by their high lubricity, stability, vapour range and non-inflammability as well as their low heat of vapourisation.

Preferably the engine is provided with means for controlling the vapour cut-off to the successive helical screw chambers and hence the chamber expansion ratio and engine torque. Expansion ratio of 1:1.5 to 1:20 are employed to advantage, the preferred range being 1:3 to 1:10 for operation without simultaneous liquid injection. Increasing the expansion ratio increases the engine's conversion efficency, while decreasing the ratio maximises output torque. By adjusting the expansion ratios the need for variable speed transmissions or torque converters is obviated, and such adjustment is achieved by varying the point at which communication between successive rotor chambers and the engine input is cut off, and this may be accomplished by providing peripherally-spaced input ports and controlling the communication between the ports and the heated vapourised drive medium. The engine vapour is advantageously directed at the leading faces of the helical chamber grooves so that the inertia of the input vapour is also converted to mechanical energy with a resulting increase in engine efficiency, particularly at high engine speeds.

A further increase in efficiency is achieved by injecting or admixing with the engine inlet vapourised drive medium, medium in the liquid state. Unlike most substances the fluorocarbon compounds suitable for use as drive media tend to superheat upon isoentropic expansion from the saturated vapour. The superheat enthalpy may be used to vapourise additional liquid drive medium within the engine, increasing the volume of vapour and furnishing additional work of expansion. The pressure required to inject the liquid into the engine may be supplied by the boiler feed or other pump. The temperature of the liquid may be as low as that of the condenser outlet, or as high as that of the hot saturated liquid in the boiler in equilibrium with the saturated vapour being used to drive the engine, or any intermediate temperature.

The proportion of liquid to be injected is readily calculable from the relative enthalpies of the liquid injected and that of the exhaust vapour that would occur without admixture of liquid. In this calculation, allowance should be made for the fact that expansion of the vapour in the engine is not truly isoentropic, hence the enthalpy and superheat of the exhaust is greater than it would be if expansion was truly isoentropic. The proportion of liquid injected into the engine should be such that the resultant exhaust, after admixture, contains a minimum of superheat. Indeed, it is preferable that the exhaust condition be within the saturation line at condenser pressure, say at 80% or 90% quality. The presence of liquid droplets suspended in the vapour materially improves sealing across lines of approximation of the surfaces of the moving engine parts and assists in lubricating them to minimise wear or damage. By such admixture of liquid with the engine inlet vapour, a greater total volume of gas passes through the engine, and the work output of the engine becomes a larger fraction of the net heat input to the boiler, resulting in improved thermal efficiency of the system. It is to be noted that this advantageous result can only be obtained with substances which superheat upon expansion of their saturated vapours.

The admixture of liquid and gas should preferably take place within the engine expansion chambers, although for practical purposes the admixture may take place at any point prior thereto, since it will require a finite period of time to reach equilibrium, which will occur under the turbulent conditions of flow within the engine. It is advantageous to inject a portion of

the liquid at relatively low temperature into the engine by such means as to cause it to flow through the bearings, thereby cooling and lubricating them. The liquid injected into the bearings at the high pressure end will admix with the vapour in the egine, increasing its efficiency as outlined above.

The fluorocarbon lubricant is admixed with the original charge of fluorocarbon drive fluid, in which it is soluble, particularly at elevated temperatures. Since the fluorosilicone is soluble therein, ebullition of the fluorocarbon in the boiler results in a vapour containing entrained microdroplets of fluorosilicone, which are carried into the engine and lubricate its moving parts. The fluorosilicone droplets dissolve in the fluorocarbon liquid in the condenser and the resultant solution has higher lubricity than the fluorocarbon alone, lubricating the boiler feed pump, circulating pump seals and all other moving parts in the system. The fluorosilicone is unaffected by the relatively low boiler temperatures required to vapourise the fluorocarbon drive medium (less than 250°C.). Hence it circulates freely and unchanged throughout the entire system. We have found that less than 1% of fluorosilicone by weight of the fluorocarbon is adequate, and 0.2% by weight is our usual proportion.

The prime mover system of the present invention employing as a drive medium the specified fluorocarbon compound and helical screw engine is far superior to a system using a fluorocarbon drive medium and conventional vapour engines in its lower cost, high efficiency, versatility and adaptability and its improved torque speed characteristics, great reliability and low maintenance. Moreover, the improved system is far superior to a corresponding system employing steam as a drive medium for similar reasons, including the poor lubricity of steam and its tendency to condense on expansion.

Referring to the accompanying drawings:

Figure 1 is a schematic diagram of a prime mover system embodying the present invention;

Figure 2 is a top plan view partially broken away, of the vapour engine forming part of the improved system;

Figure 3 is a left hand end view thereof; and

Figure 4 is a right hand end view thereof.

The reference numeral 10 designates a helical screw rotor engine which forms part of a closed vapour liquid circuit of the nature described in U.S.A. Patent No. 3,479,817 and British Specification No. 1,251,484. The engine 10 comprises a housing 11 (Fig. 2) including opposite end walls 12 and 13 and a peripheral wall 14 having a transverse cross-section delineated by intersecting circles.

A pair of mating, helical screw, male and female defining rotors 16 and 17 respectively are located in the housing 11 and are provided with axial end shafts 18 which are journalled in corresponding pairs of axially aligned bearings mounted on end plates 12 and 13, at least one of the shafts 18, for example that connected to female rotor 17, projecting by way of a suitable seal through one of the end plates and defining the engine drive or output shaft.

The rotors 16 and 17 fit in the casing 14 to close tolerances to minimise any leakage between the rotors and the peripheral and end faces of housing 11. The female rotor 17 has a plurality of similar helical chambers or cylinders defining grooves 19 formed therein, each of which extends for somewhat less than 360° about the rotor 17 from the leading to the trailing end thereof, for example six grooves 19 in the illustrated embodiment. The male rotor 16 includes a plurality of similar helical piston defining lobes 20, four in number in the illustrated embodiment. Successive lobes 20 regsister with successive grooves 19 along a longitudinally-extending intermeshing zone and form a rolling fluid tight engagement therewith with the opposite concurrent rotation of the meshing rotors 19 and 20. Thus the lobes 20 define pistons which slide along cylinder or chamber defining grooves 19 so that these successive chambers expand from the leading or input end proximate end plate 13 at the rotor intermeshing zone with the rotors 16 and 17 rotating clockwise and counterclockwise respectively as viewed in Figure 3. The lobes 20 disengage respective grooves 19 in less than one revolution and before the leading end of the respectvie groove again reaches the intermeshing zone.

A pair of pressurised vapour inlet conduits A and B respectively extend through corresponding openings in leading end plate 13 providing communication with the leading end of housing 11 and grooves 19 at a point shortly following the rotor intermeshing zone in the clockwise direction therefrom wherein the chamber in the communicating groove 19 is expanded a small predetermined amount by the mating lobe 20, and at a point further removed in the clockwise direction from the first point where the chamber in the groove 19 registering therewith is further expanded by the mating lobe 20. Thus the engine expansion chamber defined by mutual engaging groove 19 and lobe 20 is greater when communicating with conduit B than with conduit A and receives a greater volume of pressurised vapour in the former case, that is

when the pressurised vapour is fed to the chamber by conduit B or by both conduits A and B, than by conduit A alone.

A pair of exhaust conduits C and D, respectively, provide communicatoin with the grooves 19 through the trailing end plate 12 and are positioned in a manner similar to conduits A and B. Thus successive grooves 19 maintain their pressure even after they have been disengaged by corresponding lobes 20 by reason of the closure of opposite ends thereof until their trailing ends reach exhaust conduit C through which the pressurised vapour in the corresponding grooves is discharged. It should be noted that pressurised vapour may be fed to conduits C and D and conduits A and B connected to exhaust under which conditions the rotors 16 and 17 will be rotated in a reverse direction to that when the pressurised vapour is fed through conduits A and B.

The conduits A and B as well as the conduits C and D extend in a direction toward the leading face 21 of the respective groove in registry therewith, preferably perpendicular thereto. Thus, the pressurised vapour fed by any of the conduits A, B, C or D into the engine impinges on the corresponding leading groove face 21 to impart torque to the rotors as a consequence of the momentum of the inflowing vapour.

As seen in Figure 1 of the drawing the conduits A and B are connected respectively to the outlet ports 22a and 22b of a valve 22 having an inlet port 22c and the conduits C and D are connected respectively to the outlet ports 23a and 23b of a valve 23 having an inlet port 23c, the valves 22 and 23 each having actuators or spindles for selectively connecting the inlet ports to both respective outlet ports or the leading of the respective outlet ports that is ports 22a and 23a or to cut off the outlet ports. The valve inlet ports 22c and 23c are respectively connected to the outlet ports 24a and 24b of a valve 24 having inlet ports 24c and 24d which are alternatively respectively connected to the outlet ports 24a and 24b or 24b and 24a.

A drive medium heater or heat exchange unit 26 of any suitable type is heated in any suitable manner, for example by a conventional oil or gas burner, to raise the temperature of the liquid drive medium therein to close to the boiling point thereof, preferably to its neucleated boiling point, at the pressure in the heater unit, the inlet to the heater unit 26 being connected to the outlet of a condensate pump 28 which may be driven by engine 10 or by any suitable auxiliary drive means. The inlet to condensate pump 28 is connected to the outlet of a liquid drive medium reservoir tank 29 whose inlet is connected to the outlet of a heat exchange condenser unit 30 which may be suitably cooled by air or water. The inlet to codenser 30 is connected to valve port 24d.

The outlet of heater 26 is connected to the inlet of an expansion chamber 32 of the structure described in the abovementioned British Patent Specification, the vapour outlet of which is connected successively through a selectively operable throttle valve 34 to valve port 24c. The liquid outlet of expansion chamber 32 is connected to the inlet of a suitably driven liquid pump 36 to the inlet to heater 26 and through a throttle valve 37 advantageously simultaneously adjustable with throttle valve 34 to the inlet of throttle valve 34.

The circuit illustrated in Figure 1 is closed and hermetically sealed and is charged with a fluorocarbon drive medium of the nature specified above, for example, trichlorotrifluoroethane (R-113), dichlorotetrafluoroethane (R-114) and dichlorohexafluoropropane (R-216) or other fluorocarbon compounds with like properties and mixtures thereof. In addition the drive medium may have advantageously admixed therein, preferably less than 1% by weight, for example 0.2% of the drive medium, of a lubricant which is stable and inert in the drive medium and liquid at the pressures and temperatures encountered in the network, for example, the fluorosilicone lubricants. The pressures and temperatures are regulated to the desired values in the manner described in the above identified British and U.S.A. patent specifications.

Considering now the operation of the prime mover system described above, under normal forward low torque operating conditions the valve 23 is adjusted to provide communication between only ports 22a and 22c, the valve 23 is adjusted to interconnect ports 23a, 23b and 23c and valve 24 is adjusted to interconnect valve ports 24a to 24c and 24b to 24d. The drive medium is heated just to the point of nucleated boiling in heater 26 and expanded in chamber 32 to produce vapour and liquid fractions. Part of the liquid fraction is recirculated by pump 36 to the heater 26 and part through valve 37 where it is admixed with the vapour from chamber 32 flowing through valve 34. It should be noted that the flow of the liquid drive medium from chamber 32 may be completely returned to the heater 26 and none admixed with the vapour. The drive vapour, with or without any drive medium liquid enters engine 10 through conduit A, and causes the rotation of rotors 16 and 17, by reason of the pressure and expansion of the vapour, assisted by the evaporating liquid, as earlier explained, and the reaction to the inlet flow of the drive

medium. Since there is an early cut of the inlet of conduit A a relatively small amount of the drive medium enters the successive engine cylinders with a resulting high expansion ratio and low torque. The engine exhausts through conduits C and D and the exhaust flows through valves 23 and 24 and is cooled and liquefied in condenser 30 and stored in reservoir 29 from which it is pumped by pump 28 to the input of heater 26. If a greater engine output torque is desired valve 22 is adjusted to open ports 22a and 22b so that drive medium is delivered by conduits A and B to delay the vapour cut off point to a larger engine expansion chamber and deliver a greater amount of drive medium to successive chambers and hence reduce the expansion ratio and increase the engine output torque. The engine rotation is reversed merely by adjusting valve 24 so that ports 24a and 24b communicate with ports 24d and 24c respectively, the engine 10 operating reversely in a manner similar to its forward operation except that conduits A and B are now exhaust and C and D feed conduits. The engine speed may be varied by adjusting the throttle valve 34. The lubricant carried by the drive medium is circulated as described earlier.

The optimum operating parameters of the drive medium throughout the circuit and the engine expansion ratios depend on the specific drive medium and the use of liquid drive medium with the vapour. Thus expansion ratios of 1.0:1.5 to 1:20 are highly effective with expansion ratios of 1:3 to 1:10 being preferred in the absence of injected liquid drive medium. Where employed, the optimum ratio of liquid drive medium to the vapour drive medium and the optimum engine expansion ratios depend on the particular drive medium employed and other parameters and may be readily determined.

Advantageously the drive medium temperatures and pressures are 90°C to 325°C and 45 psia to 1000 psia at the engine inlet, 25°C to 150°C and 5 psi to 250 psia at the engine exhaust, 25°C to 150°C and 5 psia to 250 psia at the condenser outlet and 25°C to 150°C and 45 psia to 1000 psia at the heater inlet. The following is given by way of illustration of specific operating parameters which may be employed with the working fluids or drive mediums specified:

	R—115		R—114		R—216	
	°C	psia	°C	psia	°C	psia
Engine Inlet	170	250	155	500	170	350
Engine Exhaust	102	35	70	70	104	35
Condenser Outlet	75	35	60	70	72	45
Boiler Inlet	75	260	60	510	75	360

The desired operating parameters may be achieved in the manner described in the above identified British and U.S.A. patent specifications.

WHAT WE CLAIM IS:—

1. A prime mover system comprising a closed sealed circuit containing a drive medium having a latent heat of vapourisation of less than 100 gram calories per gram and a boiling point less than 95°C at atmospheric pressure, said closed sealed circuit comprising:

a vapour engine including at least two male and female members defining oppositely pitched helical screws intermeshing along a longitudinally extending area of engagement and extending from a leading input end to a trailing outlet end, a casing housing the screws and having faces in substantially fluid tight engagement with the peripheries of the screws and an inlet communicating with the leading section of the female screw and an outlet port communicating with the trailing end of the female screw, the female screw having chamber defining grooves and the male screw having helical lobes engaging the chambers along the intermeshing area, the screws rotating in predetermined opposite directions under the influence of a pressurised fluid introduced through the input port;

means including an input and an output for heating and vapourising the drive medium;

means including a condenser having an input and output for cooling and liquifying the drive medium;

means for injecting liquid drive medium from the cooling and liquifying means into the heating and vapourising means input;

means connecting the output of the heating and vapourising means to the input of the engine; and

means connecting the output of the engine to the input of the cooling and liquifying means.

2. A prime mover system according

to Claim 1 including means for cutting off communication between the helical chamber and the input at a predetermined position of said lobe along said helical chamber.

3. A prime mover system according to Claim 2 wherein the predetermined cut off point is adjustable.

4. A prime mover system according to Claims 1, 2 or 3, wherein the helical chamber includes a radially projecting helical first surface having a component facing a direction opposite to that of the rotation of the female screw, and means for guiding the flow of the drive medium entering the engine input port in a direction toward the first surface.

5. A prime mover system according to claim 4 wherein the angle between the direction of flow of the guided vapourised drive medium and the first surface proximate the leading section thereof is between a right angle and an obtuse angle with the flow direction being toward the axis of the respective rotor.

6. A prime mover system according to any one of the preceding claims including means alternatively connecting said heating and vapourising means output to said engine input or output and said cooling and liquifying means input to said engine output or input respectively.

7. A prime mover system according to any one of the preceding claims including means for feeding the drive medium in a liquid state into the engine input port concurrently with the drive medium in a vapour state.

8. A prime mover system according to any one of the preceding claims wherein the drive medium is selected from the group of fluorocarbon compounds containing at least 2 carbon atoms and three fluorine atoms per molecule and mixtures thereof.

9. A prime mover system according to any one of the preceding claims wherein the liquid drive medium has admixed therewith a lubricant compatible with the drive medium and liquid at the temperature and pressures of the drive medium throughout the closed circuit.

10. A prime mover system according to any one of the preceding claims wherein the temperature and pressure of the drive medium at the engine inlet are between 90°C and 325°C and between 45 psia and 1000 psia.

11. A prime mover system according to any one of the preceding claims wherein the temperature and pressure of the drive medium at the engine outlet are between 25°C and 150°C and between 5 psia and 250 psia.

12. A prime mover system according to any one of the preceding claims wherein the trailing section of the engine female screw helical chamber forward of the engagement thereof with the helical lobe communicates with the engine outlet.

13. A prime mover system according to any of the preceding claims wherein the male and female screws are multi-threaded.

14. A prime mover system according to any of the preceding claims including an adjustable throttle valve between the heating means output and the engine input.

15. A prime mover system substantially as described herein with reference to the accompanying drawings.

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1301214 COMPLETE SPECIFICATION

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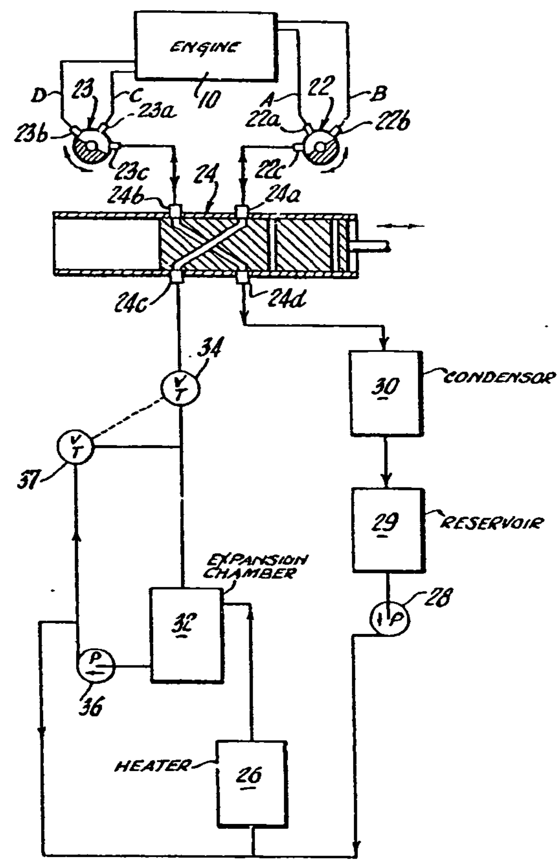
Sheet 1

Fig.1.



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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig.2.

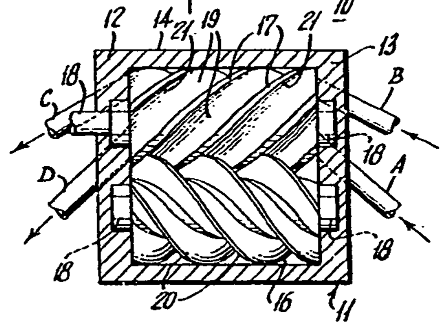

Fig.3.

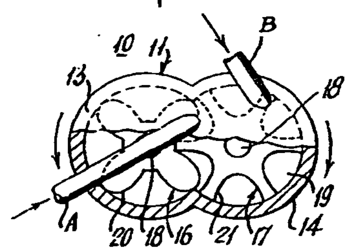

Fig.4